

RADIO INTERFACE LAYER

TECHNICAL FIELD

5 The invention generally relates to application programming interfaces (APIs) and, even more particularly, relates to a Radio Interface Layer comprising a set of APIs.

BACKGROUND

10 Cellular telephones are becoming commonplace in today's world. As users become more accustomed to using cellular telephones, they are requesting more sophisticated uses of telephones. Ideally, users would like their cellular telephones to perform the same functions as their personal computers or hand-held PDAs. Implementing such uses in a cellular
15 telephone environment requires application developers to develop or adapt their software for use on a cellular telephone. However, adapting or developing software for use on one OEM's cellular telephone does not necessarily guarantee that the software application will function on another OEM's cellular telephone due to the different radio implementations of
20 different OEMs and due to the differences in different cellular environments.

 In order to create a software solution adaptable to multiple different cellular systems and radios, there is a need for some kind of a hardware adaptation layer, i.e. a layer that isolates the specifics of a particular cellular system/hardware from the bulk of the software system. There is a further

need to expose a predefined interface used by the software components. There is still a further need that the layer should allow hardware manufacturers to replace/modify the implementation of the hardware interface to conform to their specific hardware.

5 Such a layer (TAPI) already exists for use in development of general telephony systems. However, TAPI has two disadvantages making it difficult to use in a cellular environment: a significant amount of cellular-specific functionality isn't exposed by the TAPI interface and TAPI Service Providers (TSPs) are quite difficult to implement, thus making it harder to
10 adapt the software system to different types of hardware. Hence, there is a need for a new hardware adaptation layer which is more specifically suited to the cellular environment and which simplifies the task of adapting it to different types of hardware.

15 SUMMARY OF THE INVENTION

 The present invention meets the above-described needs by providing a Radio Interface Layer (RIL), which is an API set providing a level of abstraction between the radio on a cell phone and the software of the cell phone. The API set of RIL is roughly based on the GSM AT interface as
20 defined in GSM specifications 07.05 and 07.07. The API set provides access to functionality contained within a cellular telephone, such as a GSM or CDMA compatible telephone. The present invention allows applications running on an operating system in the cellular telephone to issue commands without knowledge of the underlying radio structure of the cellular telephone

and without specific knowledge of the GSM-type commands. For example, the present invention allows the applications to access phonebook entries, restrict access to data and functionality using passwords, access file and message storage, and perform many other functions. The RIL is divided into
5 a hardware-independent proxy layer, called by various software components, and a driver layer that is hardware-specific. It should be understood that an OEM may replace the driver layer with their own layer containing implementation specific to their hardware.

That the invention improves over the drawbacks of the prior art and
10 accomplishes the advantages described above will become apparent from the following detailed description of the exemplary embodiments and the appended drawings and claims.

BRIEF DESCRIPTION OF THE FIGURES

15 Figure 1 is a block diagram of an exemplary personal computer system.

Figure 2 is a block diagram illustrating an exemplary embodiment of an RIL in a phone in accordance with an embodiment of the present invention.

20 Figure 3 is a flow diagram illustrating a method for processing of commands using the radio interface layer (RIL) in accordance with an embodiment of the present invention.

Figure 4 is a block diagram illustrating a method for an application to establish a voice call using RIL in accordance with an embodiment of the present invention.

5 DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

An embodiment of the present invention will be incorporated into a cellular telephone marketed by Microsoft Corporation of Redmond, Washington. The cellular telephone may be a "smart phone" that, in addition to providing telephony services, also runs different software applications and performs different functions normally reserved for personal computers or PDAs. For example, in one embodiment, the telephone may be used as a personal information manager (PIM) for storing appointments, contacts, tasks, etc.

Other embodiments of the present invention may be incorporated into PDAs, personal computers and hand-held computers. Fig. 1 and the following discussion are intended to provide a brief, general description of an exemplary personal computer system for use with the above-described embodiments of the present invention. Those skilled in the art will recognize that software products may include routines, programs, components, data structures, etc. that perform particular tasks or implement particular abstract data types. Moreover, those skilled in the art will appreciate that the invention may be practiced with other computer system configurations, including hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics,

minicomputers, mainframe computers, and the like. The invention may also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment,
5 software products may be located in both local and remote memory storage devices.

With reference to Fig. 1, an exemplary system for implementing the invention includes a conventional personal computer 20, including a processing unit 21, a system memory 22, and a system bus 23 that couples
10 the system memory to the processing unit 21. The system memory 22 includes read only memory (ROM) 24 and random access memory (RAM) 25. A basic input/output system 26 (BIOS), containing the basic routines that help to transfer information between elements within the personal computer 20, such as during start-up, is stored in ROM 24. A video BIOS
15 60 may also be stored in ROM 24. The personal computer 20 further includes a hard disk drive 27, a magnetic disk drive 28, e.g., to read from or write to a removable disk 29, and an optical disk drive 30, e.g., for reading a CD-ROM disk 31 or to read from or write to other optical media. The hard disk drive 27, magnetic disk drive 28, and optical disk drive 30 are
20 connected to the system bus 23 by a hard disk drive interface 32, a magnetic disk drive interface 33, and an optical drive interface 34, respectively. The drives and their associated computer-readable media provide nonvolatile storage for the personal computer 20. Although the description of computer-readable media above refers to a hard disk, a removable magnetic

disk and a CD-ROM disk, it should be appreciated by those skilled in the art that other types of media which are readable by a computer, such as magnetic cassettes, flash memory cards, digital video disks, Bernoulli cartridges, and the like, may also be used in the exemplary operating
5 environment.

A number of software products may be stored in the drives and RAM
25, including an operating system 35, a software product 36, such as Microsoft's "OFFICE XP" suite of application program modules, other software products 37, and program data 38. A user may enter commands
10 and information into the personal computer 20 through a keyboard 40 and pointing device, such as a mouse 42. Other input devices (not shown) may include a microphone, joystick, game pad, satellite dish, scanner, or the like. These and other input devices are often connected to the processing unit 21 through a serial port interface 46 that is coupled to the system bus, but may
15 be connected by other interfaces, such as a game port or a universal serial bus (USB). A monitor 47 or other type of display device is also connected to the system bus 23 via an interface, such as a video adapter 48. In addition to the monitor, personal computers typically include other peripheral output devices (not shown), such as speakers or printers.

20 The personal computer 20 may operate in a networked environment using logical connections to one or more remote computers, such as a remote computer 49. The remote computer 49 may be a server, a router, a peer device or other common network node, and typically includes many or all of the elements described relative to the personal computer 20, although

only a memory storage device 50 has been illustrated in Fig. 1. The logical connections depicted in Fig. 1 include a local area network (LAN) 51 and a wide area network (WAN) 52. Such networking environments are commonplace in offices, enterprise-wide computer networks, Intranets and the Internet.

When used in a LAN networking environment, the personal computer 20 is connected to the LAN 51 through a network interface 53. When used in a WAN networking environment, the personal computer 20 typically includes a modem 54 or other means for establishing communications over the WAN 52, such as the Internet. The modem 54, which may be internal or external, is connected to the system bus 23 via the serial port interface 46. In a networked environment, program modules depicted relative to the personal computer 20, or portions thereof, may be stored in the remote memory storage device. It will be appreciated that the network connections shown are exemplary and other means of establishing a communications link between the computers may be used.

Radio Interface Layer

In one embodiment, the present invention, known as the Radio Interface Layer (RIL) comprises an API set which provides a level of abstraction between the radio on a cell phone and the software of the cell phone. The API set of RIL is based on the GSM AT interface as defined in GSM specifications 07.05 and 07.07. The API set provides access to functionality contained within a cellular telephone, such as a GSM or CDMA compatible telephone. The present invention allows applications

running on an operating system in the cellular telephone to issue commands without knowledge of the underlying radio structure of the cellular telephone and specific knowledge of the GSM-type commands. For example, the present invention allows the applications to access phonebook entries, restrict access to data and functionality using passwords, access file and message storage, and perform many other functions.

The RIL is divided into a hardware-independent proxy layer, called by various software components, and a driver layer that is hardware-specific. It should be understood that an original equipment manufacturer (OEM) may replace the driver layer with their own layer containing implementation specific to their hardware. In a preferred embodiment, the RIL is a core component of a cellular telephone marketed by Microsoft Corporation of Redmond, Washington.

RIL Driver Layer

In a preferred embodiment, the Radio Interface Layer (RIL) driver layer is used to implement and roughly correspond to the commands, such as AT commands, specified by ETS 300 585, Digital cellular telecommunications system (Phase 2); Use of Data Terminal Equipment–Data Circuit terminating Equipment (DTE-DCE) interface for Short Messaging Service (SMS) and Cell Broadcast Service (CBS) (GSM 07.05), Fifth Edition, April 1997, and ETS 300 642, Digital cellular telecommunications system (Phase 2); AT command set for GSM Mobile Equipment (ME) (GSM 07.07 version 4.4.1), Fourth Edition, March 1999. The GSM specifications 07.05 and 07.07 are hereby incorporated by

reference. Of course, the RIL driver may be used to implement and correspond to other command sets, such as CDMA commands, or a combination of several command sets.

OEMs may use the RIL driver of the preferred embodiment or tweak it if they would rather talk with their radio over private APIs instead of via AT commands (most likely for performance reasons).

Generally described, the RIL driver layer receives an RIL API call and causes the radio (i.e. the receiver/transmitter of the cellphone, PDA, etc.) to perform the function defined by the RIL API. In a preferred embodiment, the RIL driver will receive the RIL API call from a RIL proxy layer (described below). The RIL driver layer also processes notifications received from the radio and transmits them to the RIL proxy layer. In a preferred embodiment, the RIL driver layer is a dynamic link library (DLL) that is running as a device driver inside the process space of a device manager (the standard module that manages device drivers on the “WINDOWS CE” operating system). A Device Manager (device.exe) may be responsible for managing all the system drivers, including the RIL driver.

RIL Proxy Layer

In one embodiment, the RIL proxy layer comprises a layer that is called by various other layers of the core architecture, such as a TSP layer, an ExtAPI layer, and a SIM Manager using the platform specific commands of these core architectures. In a preferred embodiment, the proxy layer is a “WINDOWS CE” dynamic link library (DLL) that manages callback notifications and inter-process function calls into the RIL driver layer.

Modules that want to use the RIL simply link with this proxy DLL. The RIL proxy layer converts the core architecture specific commands into RIL API calls that will be understood by the RIL driver layer.

There are some important distinctions between the proxy and driver layers. In a preferred embodiment of the invention, a separate proxy instance is created for each module using the RIL proxy DLL. On the other hand, in a preferred embodiment of the invention, the RIL device driver is loaded only once and is shared amongst all proxy layer instances. In other words, a module using the RIL must be aware that only one radio module exists, even though it links to its own proxy DLL. In addition, the Device Manager's control of the RIL driver implies that the proxy and driver live in separate processes (i.e. different address spaces). However, the "WINDOWS CE" operating system exposes mechanisms allowing the proxy and driver layers to communicate without being concerned with the process boundaries.

Another important architectural property of the RIL is that almost all of the functions are asynchronous. When a module first registers with the RIL, it passes in two callback functions. One is used for unsolicited notifications, and the other is used for responses to function calls. For instance, when the phone receives a new incoming call, RIL will use the unsolicited notification callback to let each module know about the incoming call. Alternately, when a module calls RIL to obtain the signal strength, the function call immediately returns a response identifier. Shortly thereafter, RIL uses the function response callback to convey signal strength

information to the module. To ensure that function response callbacks are correctly matched up with function calls, this callback structure also contains the same response identifier value returned by the original function call. This asynchronous architecture simplifies RIL implementation. If a module
5 needs to call RIL functions in a synchronous manner, it will need to make the function call and block until it receives the function response callback.

Another architectural feature of the RIL is a virtual serial port (VSP). When an application makes a data connection, it retrieves a handle to a virtual serial port (not the real data stream between the RIL and the radio).

10 This allows RIL to buffer and flow control the data stream so that control commands can be interjected. For example, suppose an application has set up a data connection and is browsing on the Internet. The virtual serial port allows RIL to interject control commands to check for things like signal strength, new SMS messages, etc. However, further suppose an application
15 is receiving a facsimile. Due to strict timing issues in the case of a facsimile transmission, the RIL will enter a dedicated data mode where the application has full control of the virtual serial port. That is, RIL will not attempt to interject any commands in the data stream. It should be understood that the VSP is similar to other communication ports and typically only one
20 application can have the handle to the VSP at one time.

Referring now to Figure 2, a block diagram illustrating an exemplary embodiment of an RIL in a cellphone 200 in accordance with an embodiment of the present invention will be described. The cellphone 200 comprises a SIM manager 205, an emergency application 210, a TAPI

Service Provider (TSP) 215, a WAP layer 220, a SMS manager 225, a data stack 230 and a VSP 250.

The cellphone 200 further comprises a plurality of instances of the RIL proxy layer 235. The RIL proxy layer 235 provides communications
5 between applications (such as the SIM manager 205, emergency application 210, TSP 215, WAP layer 220, SMS manager 225, and ExTAPI, among others) and a RIL driver layer 240. The RIL driver layer 240 provides communications between the RIL proxy layer and the radio hardware 245.

Scenarios

10 In terms of “using” the RIL (from the point of view of both an application designer and an OEM), the proxy and driver layers each expose a set of functions. For a program module to use the RIL, it only needs to use functions specified in the proxy header file and then link with the proxy DLL. The proxy DLL is implemented by calling functions specified in the
15 driver header file. The driver header file is provided to OEMs and defines the functions that an OEM must implement. In one embodiment, the implementation will be hardware specific, so each OEM will be responsible for its own driver implementation. However, one or more reference implementations of the driver (source code included) may be provided to
20 OEMs to help them with this step. If an OEM uses radio hardware that is supported by one of these reference implementations, it may not need to revise the RIL code.

Method for Processing Commands Using RIL

Figure 3 is a flow diagram illustrating a method 300 for processing of commands using the radio interface layer (RIL) in accordance with an embodiment of the present invention. The method 300 begins at step 305 when a user calls a RIL API in the proxy layer.

At decision step 310, it is determined whether the callee, i.e. the called process, is in the device.exe process space. If it is, then the method proceeds to step 315 where the driver APIs are called directly. If it is determined at decision step 310 that the callee is not in the device.exe process space then the method proceeds to step 320.

At step 320, input/output control (IOCTL) codes are used to send the appropriate information for the RIL API to the RIL driver running in a separate process space. At step 325, the RIL driver informs the radio to take the action specified by the command of the RIL API. In a preferred embodiment, the RIL driver informs the radio to take action using an AT command interface, as defined in GSM specs (most prominently 07.05 and 07.07). However, sending AT commands may not be ideal for a given radio—perhaps an OEM has a separate private API set that they can use to perform the same functionality as a given AT command. If this is the case, the OEM may change the RIL driver to suit their needs. However, in a preferred embodiment, because the core architecture of the phone has been built on top of a set of RIL APIs that may be implemented via AT commands, it is not necessary for the OEM to substantially modify the RIL driver so long as the radio understands AT commands. However, due to

different implementations of the AT interface, some minor modifications may be necessary.

The method then proceeds to step 330 where the RIL API returns with a unique ID generated by the RIL. It should be understood that after sending
5 an AT command, a response from the radio unit is awaited. RIL APIs are designed to be asynchronous, so these APIs will return immediately, with a unique ID assigned to the call.

The method then proceeds to step 335 where a separate thread waits for responses from the radio unit.

10 The method then proceeds to step 340 where the RIL driver matches the response from the radio unit with the unique ID generated earlier and the RIL driver sends the response to the appropriate calling process via a callback function.

It should also be understood that radio units can also send unsolicited
15 notifications (for example, when the phone switches cellular towers). In this case, the RIL driver receives a notification from the radio and will broadcast a message to all users of the RIL layer who are interested in this class of notification.

For an example illustrating an implementation of method 300,
20 consider the following: the API RIL_ChangeLockingPassword is a RIL API that allows changing the password of a phone for various lock facilities. This API is modeled after the +CPWD AT command, defined in section 7.5 of GSM 07.07. The AT command to change a password requires a lock

facility, the old password, and the new password. Accordingly, the API for RIL_ChangeLockingPassword appears as:

```
HRESULT RIL_ChangeLockingPassword(  
    HRIL hRil,  
5    DWORD dwFacility,  
    LPCSTR lpszOldPassword,  
    LPCSTR lpszNewPassword  
);
```

When the user application wants to change the locking password, it
10 calls this API, typically indirectly via a TAPI layer or another layer. For
example, the application may understand the TAPIcommand for changing a
password and send this command to the TAPI layer. The TAPI layer will
then make the appropriate RIL API call to the proxy layer. As part of the
RIL API, a RIL handle must be provided (which is obtained from initializing
15 RIL), a locking facility must be provided, the old password must be provided
and the new password must be provided. For example, suppose a user
application wishes to change the password used to lock the SIM card from
“1234” to “5678”. The user application (or an intermediate layer such as the
TAPI layer) would make the following API call:

```
20    RIL_ChangeLockingPassword(hRIL,    RIL_LOCKFACILITY_SIM,  
    “1234”, “5678”);
```

If the calling process is not in the device.exe, these parameters will get
bundled into a structure and passed via an IOCTL call,
RIL_IOCTL_CHANGELOCKINGPASSWORD:

```

typedef struct changelockingpassword_params_tag {
    DWORD dwfacility;
    char szOldPassword[MAXLENGTH_PASSWORD];
    char szNewPassword[MAXLENGTH_PASSWORD];
5 }
CHANGELOCKINGPASSWORD_PARAMS,*LPCHANGELOCKINGPA
SSOWRD_PARAMS;

```

The RIL driver will then take these constants and generate an AT command string as specified in GSM 07.07:

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10 AT+CPWD=SC,1234,5678

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Note that if an OEM were to change the RIL driver to call a private API to their radio instead of using an AT command, they would make their change at this point.

```

15 After sending this AT command (or private API) to the radio, the RIL
driver returns, and RIL_ChangeLockingPassword returns. The radio has not
yet processed the command at this point, so a unique ID is givenback to the
user as the return value of this RIL API.

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20 After processing the command, the radio module will return a success
or error code (in this case, there will be a success code or a possibly
descriptive error code such as "wrong password"). The radio gives this
response to the RIL driver, which has a separate thread waiting for responses
from the radio module. This response is then matched with the unique ID
from the API call and sent via a callback function to the calling process. The

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calling process can then note whether the locking password was successfully changed or not and act accordingly.

Referring now to Figure 4, an example illustrating a method for an application to establish a voice call using RIL in accordance with an embodiment of the present invention will be described. It should be understood that establishing a voice call is only one of many functions that may be performed using the RIL APIs. The method outlined in Figure 4 is illustrative of one of these functions (establishing a voice call). The method is implemented in telephone 400 that includes an application layer 405, an ExTAPI layer 410, a TAPI layer 415, other core modules 420, a TSP 425, a radio interface layer (RIL) 430 in accordance with an embodiment of the invention, and OEM hardware 435. It should be understood that the method does not describe the IOCTLs which will be understood by those skilled in the art to be present in a preferred embodiment. It should be further understood that the present invention may be implemented without the use of IOCTLs.

The method begins when application 405 calls the TAPI function: lineMakeCall (step 452). The TAPI layer 415 calls the TSP 425 with the following function call: TSPI_lineMakeCall (step 454). The TSP 425 calls the RIL with the following RIL function: RIL_Dial (step 456). The RIL initiates the phone call by sending the corresponding command to the OEM hardware (e.g. radio): e.g. ATDT 555-1234 (step 458). The TSP returns asynchronously a reply message to the TAPI layer indicating that the call has been initiated: LINE_REPLY message (step 460).

The TAPI layer forwards the reply message (LINE_REPLY) to the application (step 462). When the OEM hardware detects that a connection to the number has been made, then it sends a CONNECT response to the RIL (step 464). The RIL sends a message (RIL_NOTIFY_CONNECT) to the TSP indicating that a connection has been made (step 466). The TSP sends a state change message (LINE_CALLSTATE) to the TAPI layer (step 468). The TAPI layer forwards the state change message (LINE_CALLSTATE) to the application 405 (step 470).

When the application 405 wishes to drop the telephone call, it calls the TAPI layer with a hang-up request: (lineDrop) (step 472). The TAPI layer forwards the TSP the hang-up request: (TSPI_lineDrop) (step 474). The TSP handler passes the hang-up request to the RIL: (RIL_Hangup) (step 476). The RIL passes the hang-up request to the OEM hardware (e.g. ATH) (step 478).

Features

The following table describes some of the features that may be implemented using an embodiment of the present invention and a brief description of these features.

Name	Description
Network Services	Operator selection, signal status, available operators, etc.
Call Control	Dial, Hangup, Hold, Transfer, etc.
Supplemental Services	Call waiting, call forwarding, call meter, etc.
SMS	Send, receive, SMSC selection, etc.
Data Connection	Virtual serial port, bearer service types, transparent data/online mode change
Security Functions	Locking, unlocking, passwords, etc.
Interface Functions	Initialization, notification registration, etc.
Phonebook Functions	Accessing the SIM phonebooks
SIM SMS Functions	Accessing SMS messages from the SIM

Name	Description
GPRS Functions	Selecting profiles, attaching, activating, etc.
HSCSD Functions	Managing channel allocations
SIM Record Access	Access individual files on the SIM
SIM Toolkit 2.0 Support	Engaging in a SIM toolkit session

Structure Listing

This section describes the “data structures” passed as parameters to some RIL APIs and returned with some RIL notifications in an embodiment of the present invention.

Network Service Structures

Structure	Comments
RILSUBSCRIBERINFO	Defines an assigned phone number and parameter associated with it
RILOPERATORNAMES	Defines the long, short, and numeric format of a single operator
RILOPERATORINFO	Defines a network operator

Call Control Structures

Structure	Comments
RILCALLINFO	Defines each call instance (active, on hold, in conference, etc.)
RILRINGINFO	Indicates the type of incoming call

Supplemental Service Structures

Structure	Comments
RILCALLFORWARDSETTING S	Defines call forwarding
RILCALLWAITINGINFO	Information about an incoming call
RILCALLERIDSETTINGS	Defines caller ID
RILHIDEIDSETTINGS	Defines how to hide your phone number when calling someone else
RILDIALEDIDSETTINGS	Defines the true number that was dialed
RILCLOSEDGROUPSETTING S	Defines closed user group settings
RILREMOTEPARTYINFO	Structure used for CallerID and DialedID notifications

Voice Structures

Structure	Comments
RILGAININFO	Defines audio gain for the transmit and receive channels
RILAUDIODEVICEINFO	Defines transmit and receive audio devices

5 Messaging Structures

Structure	Comments
RILMSGSERVICEINFO	Messaging settings such as storage locations and usage info
RILMSGDCS	Data coding scheme
RILMSGCONFIG	Messaging configuration
RILMESSAGE	An actual message
RILMESSAGEINFO	Contains an RILMESSAGE along with additional info
RILMSGSTORAGEINFO	Information about a message storage location

Data Service Structures

Structure	Comments
RILCALLHSCSDINFO	Defines HSCSD parameters for the current call
RILHSCSDINFO	Defines HSCSD parameters
RILDATACOMPINFO	Defines parameters for data compression
RILERRORCORRECTIONINFO	Defines parameters for error correction
RILBEARERSVCINFO	Defines the current data communication settings
RILRLPINFO	Defines Radio Link Protocol (RLP) parameters for non-transparent data calls
RILCONNECTINFO	Defines connect information on a data call
RILSERIALPORTSTATS	Defines statistics of the virtual serial port
RILSERVICEINFO	Defines parameters of the data connection
RILSUPSERVICEDATA	Defines elements of a USSD message

Capability Structures

Structure	Comments
RILCAPSBEARERSVC	Bearer service capabilities
RILCAPSDIALSVC	Dial capabilities
RILCAPSHSCSD	HSCSD capabilities

Structure	Comments
RILCAPSLOCKINGPWDLENGTH	Locking password length capabilities
RILCAPSMSMEMORYLOCATIONS	Message storage location capabilities
RILCAPSRLP	RLP capabilities

SIM Toolkit Structures

Structure	Comments
RILSIMCMDPARAMETERS	Elements of a SIM command
RILSIMRESPONSE	Elements of a SIM command response

Miscellaneous Structures

Structure	Comments
RILEQUIPMENTINFO	Defines miscellaneous (generally static) properties of radio module
RILPHONEBOOKINFO	Defines the state of the phonebook
RILPHONEBOOKENTRY	Defines an entry in the phonebook
RILCOSTINFO	Defines cost information for the current operator's rate
RISIGNALQUALITY	Defines the current signal quality
RILADDRESS	A phone number
RILSUBADDRESS	More detailed information about a phone number
RILCELLTOWERINFO	Information about the currently registered cell tower
RILRANGE	Defines a min/max range

5

Notification Listing

This section lists some of the unsolicited RIL notifications that get passed to the notification callback. Note that these notifications differ from the ones passed to the response callback as responses to earlier issued function calls. These notifications have been categorized for convenience. These notifications are in one embodiment of the invention and are not meant to limit the invention. dwCode is the numeric ID identifying the notification and lpData is the additional data returned with the notification.

DwCode	lpData	Comments
RIL_NOTIFY_REGSTATUSCHANGED	(RIL_REGSTAT_*) Constant	Sent with change in registration status
RIL_NOTIFY_CALLMETER	dwNewCallMeter	Call meter has changed
RIL_NOTIFY_CALLMETERMAXREACHED	<NULL>	Maximum call meter has been reached

Call Control Notifications

DwCode	lpData	Comments
RIL_NOTIFY_RING	RILRINGINFO Structure	Incoming call
RIL_NOTIFY_CONNECT	RILCONNECTINFO Structure	Call connected
RIL_NOTIFY_DISCONNECT	RIL_DISCINIT_* Constant	Call disconnected
RIL_NOTIFY_DATASVCNEGOTIATED	RILSERVICEINFO Structure	Data call service has been negotiated
RIL_NOTIFY_CALLSTATECHANGED	<NULL>	Call state of one or more calls may have changed
RIL_NOTIFY_EMERGENCYMODEENTERED	<NULL>	RIL has entered emergency mode
RIL_NOTIFY_EMERGENCYMODEEXITED	<NULL>	RIL has exited emergency mode
RIL_NOTIFY_EMERGENCYHANGUP	<NULL>	Existing calls (if any) were hung up for emergency mode
RIL_NOTIFY_HSCSDPARAMSNEGOTIATED	RILCALLHSCSDINFO Structure	HSCSD parameters for a call have been negotiated

5

Supplemental Service Notifications

DwCode	LpData	Comments
RIL_NOTIFY_CALLERID	(RILREMOTEPARTYINFO *)	The remote address of the incoming call
RIL_NOTIFY_DIALEDID	(RILREMOTEPARTYINFO *)	The destination address of the outgoing call
RIL_NOTIFY_CALLWAITING	(RILCALLWAITINGINFO *)	Call waiting notification
RIL_NOTIFY_SUPPLEMENTALSERVICEDATA	(RILSUPPLEMENTALSERVICEDATA *)	Incoming USSD message

Messaging Notifications

dwCode	lpData	Comments
RIL_NOTIFY_MESSAGE	(RILMESSAGE *)	Indicates a new message
RIL_NOTIFY_BCMESSEGE	(RILMESSAGE *)	Indicates a new broadcast message
RIL_NOTIFY_STATUSMESSAGE	(RILMESSAGE *)	Indicates a new status message
RIL_NOTIFY_MSGSTORED	(dwIndex)	Indicates a message has been stored
RIL_NOTIFY_MSGDELETED	(dwIndex)	Indicates a message has been deleted
RIL_NOTIFY_MSGSTORAGECHANGED	RILMSGSTORAGEINFO Structure	One of the message storage locations has been changed

Phonebook Notifications

dwCode	lpData	Comments
RIL_NOTIFY_PHONEBOOKENTRYSTORED	dwIndex	Phonebook entry has been added
RIL_NOTIFY_PHONEBOOKENTRYDELETED	dwIndex	Phonebook entry has been deleted
RIL_NOTIFY_PHONEBOOKSTORAGECHANGED	(RIL_PBLOC *) Constant	Phonebook storage location has been changed

5

SIM Toolkit Notifications

dwCode	lpData	Comments
RIL_NOTIFY_SIMTOOLKITCMD	dwByteCount	Proactive SIM command received
RIL_NOTIFY_SIMTOOLKITCALLSETUP	dwRedialTimeout	Proactive SIM command to setup a call
RIL_NOTIFY_SIMTOOLKITEVENT	dwByteCount	Toolkit command was handled by the radio or radio sent a toolkit response to the SIM

Miscellaneous Notifications

dwCode	lpData	Comments
RIL_NOTIFY_SMSNOTACCESSIBLE	<NULL>	Sim has been removed or has failed to respond
RIL_NOTIFY_DTMFSIGNAL	(char*)	A DTMF signal has been detected

Function Listing

This section lists some of the RIL functions broken down by group. Each entry denotes the function name, and a brief description. Where applicable, the corresponding GSM AT command is included.

5

Network Service Functions

Function	GSM	Comments
RIL_GetSubscriberNumbers	+CNUM	Gets list of assigned phone numbers
RIL_GetOperatorList	+COPS	Gets a list of available operators
RIL_GetPreferredOperatorList	+CPOL	Gets a list of preferred operators
RIL_AddPreferredOperator	+CPOL	Adds to the list of preferred operators
RIL_RemovePreferredOperator	+CPOL	Removes from the list of preferred operators
RIL_GetCurrentOperator	+COPS	Gets the operator currently registered
RIL_RegisterOnNetwork	+COPS	Register with a particular operator
RIL_UnregisterFromNetwork	+COPS	Unregister current operator
RIL_GetRegistrationStatus	+CREG	Gets registration status

Call Control Functions

Function	GSM	Comments
RIL_Dial	D +FCLASS	Dials a number
RIL_Answer	A	Answers an incoming call
RIL_Hangup	H	Sets operator information
RIL_SendDTMF	+VTS	Sends DTMF tones (e.g. during a call)
RIL_GetDTMFDuration	+VTD	Gets tone duration options
RIL_SetDTMFDuration	+VTD	Sets tone duration options
RIL_SetDTMFMonitoring		Turns on/off DTMF monitoring
RIL_GetCallList	+CLCC	Retrieves list of active calls and their status
RIL_ManageCalls	+CHLD	Changes call status (hold, conference, etc)
RIL_TransferCall	+CTFR	Explicitly transfers a call
RIL_GetLineStatus	+CPAS	Gets line status

10

Supplemental Service Functions

Function	GSM	Comments
RIL_SetCallerIDSettings	+CLIP	CallerID settings
RIL_GetHideIDSettings	+CLIR	Hides own number from recipient
RIL_SetHideIDStatus	+CLIR	Hides own number from recipient
RIL_GetDialedIDSettings	+COLP	Dialed number on an outgoing call
RIL_SetDialedIDSettings	+COLP	Dialed number on an outgoing call
RIL_GetClosedGroupSettings	+CCUG	Closed user group settings
RIL_SetClosedGroupSettings	+CCUG	Closed user group settings
RIL_GetCallForwardSettings	+CCFC	Call forward settings
RIL_AddCallForwarding	+CCFC	Add a number to the call forwarding list
RIL_RemoveCallForwarding	+CCFC	Remove a number from the call forwarding list
RIL_SetCallForwardStatus	+CCFC	Enable/disable call forwarding
RIL_GetCallWaitingSettings	+CCWA	Call waiting settings
RIL_SetCallWaitingStatus	+CCWA	Call waiting settings

Voice Functions

Function	GSM	Comments
RIL_GetAudioGain	+VGR +VGT	Gets receive gain of the audio device
RIL_SetAudioGain	+VGR +VGT	Sets receive gain of the audio device
RIL_GetAudioDevices	+VGS	List connected audio devices (mic, speaker, etc)
RIL_SetAudioDevices	+VGS	Sets connected audio devices (mic, speaker, etc)
RIL_GetAudioMuting	+CMUT	Gets muting state
RIL_SetAudioMuting	+CMUT	Sets muting state

5

Messaging Functions

Function	GSM	Comments
RIL_GetMsgServiceOptions	+CSMS +CPMS +CMGF +CESP	Gets messaging service options
RIL_SetMsgServiceOptions	+CSMS +CPMS +CMGF +CESP	Sets messaging service options
RIL_GetMsgConfig	+CSCA +CSMP +CSDH +CSCB	Gets message configuration options
RIL_SetMsgConfig	+CSCA +CSMP +CSDH +CSCB	Sets message configuration options

Function	GSM	Comments
RIL_RestoreMsgConifg	+CRES	Restores messaging settings
RIL_SaveMsgConfig	+CSAS	Saves messaging settings
RIL_GetMsgList	+CMGL	Lists all messages
RIL_ReadMsg	+CMGR +CMGD	Read (optionally delete) a message
RIL_DeleteMsg	+CMGD	Delete a message
RIL_WriteMsg	+CMGW +CMGS +CMMS	Writes (optionally send) a message
RIL_SendMsg	+CMGS +CMSS +CMMS	Send a message
RIL_SendStoredMsg	+CMGS +CMSS +CMMS	Send a message from a storage location
RIL_SendMsgAcknowledgement	+CMGS +CMSS +CMMS	Send a message ACK when requested by an incoming message

Data Service Functions

Function	GSM	Comments
RIL_GetSerialPortHandle		Gets a virtual serial port handle
RIL_GetSerialPortStatistics		Gets statistics on the virtual serial port handle
RIL_GetHSCSDOptions	+CHSD +CHDT +CHSN +CHSC +CHSR	Get settings for circuit switched data calls
RIL_SetHSCSDOptions	+CHSD +CHDT +CHSN +CHSC +CHSR	Set settings for circuit switched data calls
RIL_GetDataCompression	+DS	Gets data compression options
RIL_SetDataCompression	+DS	Sets data compression options
RIL_GetErrorCorrection	+EX	Gets error correction options
RIL_SetErrorCorrection	+EX	Sets error correction options
RIL_GetBearerServiceOptions		
RIL_SetBearerServiceOptions		
RIL_GetRLPOptions		Gets radio link protocol options
RIL_SetRLPOptions		Sets radio link protocol options
RIL_CancelSupServiceDataSession	+CUSD	Cancel a USSD session
RIL_SendSupServiceData	+CUSD	Send a USSD message

Security Functions

Function	GSM	Comments
RIL_GetUserIdentity	+CIMI	Retrieve the customer's mobile identity
RIL_UnlockPhone	+CPIN	Sends a pending password
RIL_ChangeCallBarringPassword	+CPIN +CPWD	Changes the call barring password
RIL_ChangeLockingPassword	+CPIN +CPWD	Changes the locking password
RIL_GetPhoneLockedState	+CPIN	Gets phone lock status
RIL_GetCallBarringStatus	+CLCK	Gets call barring status
RIL_SetCallBarringStatus	+CLCK	Sets call barring status
RIL_GetLockingStatus	+CLCK	Gets locking status
RIL_SetLockingStatus	+CLCK	Sets locking status

Interface Functions

Function	GSM	Comments
RIL_Initialize		Registers RIL proxy with RIL driver
RIL_Deinitialize		Unregisters RIL proxy from RIL driver
RIL_InitializeEmergency		Registers an emergency application
RIL_DeinitializeEmergency		Unregisters an emergency application
RIL_EnableNotifications		Sets which notification classes to receive
RIL_DisableNotifications		Disables notification classes from being sent

Phonebook Functions

Function	GSM	Comments
RIL_GetPhonebookOptions	+CPBS	Gets the phonebook options
RIL_SetPhonebookOptions	+CPBS	Sets the phonebook location
RIL_DeletePhonebookEntry	+CPBW	Deletes a phonebook entry
RIL_ReadPhonebookEntries	+CPBR	Get phonebook entry
RIL_WritePhonebookEntry	+CPBW	Writes a phonebook entry

SIM Toolkit Functions

Function	GSM	Comments
RIL_FetchSimToolkitCmd	+CSIM	Retrieves a proactive toolkit command
RIL_GetSimToolkitProfile		Retrieves a current profile for a profile download
RIL_SetSimToolkitProfile		Sets current profile for a profile download

Function	GSM	Comments
RIL_SendSimToolkitCmdResponse	+CSIM	Sends a response to a proactive toolkit command
RIL_SendSimToolkitEnvelopeCmd	+CSIM	Sends an envelope command to the SIM
RIL_TerminateSimToolkitSession	+CSIM	Terminates a toolkit session

Miscellaneous Functions

Function	GSM	Comments
RIL_GetEquipmentInfo	+CGMI GMI +CGMM GMM +CGMR GMR +CGSN GSN	Retrieves information about the phone equipment
RIL_GetEquipmentState	+CFUN	Manages phone state (power management)
RIL_SetEquipmentState	+CFUN	Manages phone state (power management)
RIL_SendSimCmd	+CSIM	Sends unrestricted commands directly to a SIM
RIL_SendRestrictedSimCmd	+CRSM	Sends a restricted set of commands directly to a SIM
RIL_ResetTerminal	Z &F	Resets all terminal parameters to defaults
RIL_GetCostInfo	+CAOC +CPUC	Retrieves advice of charge information
RIL_SetCostInfo	+CAOC +CPUC	Sets advice of charge information
RIL_GetSignalQuality	+CSQ	Gets signal quality
RIL_GetDevCaps		Retrieves the capabilities of the radio device
RIL_DevSpecific		Developer specific command
RIL_GetCellTowerInfo	+CREG	Gets info about the currently used cell tower

It should be understood from the foregoing description that the RIL proxy layer is hardware-independent. In contrast, it should be understood that in different embodiments, the RIL driver layer is hardware-specific. However, in one embodiment, a sample GSM implementation of the RIL driver is provided to function with generic GSM hardware (although, in practice, some modifications will probably be needed for almost any GSM system currently in existence because the GSM specifications may be interpreted and implemented slightly differently by different OEMs).

It should be also understood from the foregoing description, that the present invention allows software applications to function on RIL-compatible phones independently of the hardware or the cellular network being used. For example, changing from a GSM to a CDMA network would only require replacing the RIL driver layer and the rest of the phone would work as it did in the GSM network.

It should be understood from the foregoing description that the purpose of the RIL is to provide access to cellular functionality for any component in the phone, PDA, etc. Without the RIL, each component (TAPI, SIM manager, SMS manager, etc.) of the phone would have to understand how to communicate to the radio directly. Because it would be difficult for hardware manufacturers to implement a TAPI driver, a SMS driver, a SIM driver, etc., the RIL was created to sit between the radio and the TAPI driver, the SMS driver, the SIM driver, etc.

It should be also be understood from the foregoing description, that because the RIL proxy is hardware-independent, RIL provides a platform for third party software developers. With the well-designed APIs and interfaces of the RIL of the present invention, a third party software developer may write his code once and have it work on all devices containing an implementation of RIL, such as telephones, PDAs, etc. Moreover, the software developer may use the well-defined telephony commands such as TAPI without worrying about whether the underlying device is using cellular technology, voice over IP, etc.

It should be understood that one of the objectives of RIL is to ease the integration process of software components with an OEM's hardware components. To realize this, a single layer handles all communication between the core modules and an OEM's radio hardware. The single RIL
5 allows software components to be designed without having to worry about differences in underlying hardware. It also allows OEMs to integrate the software components with their radio hardware by implementing a single set of functions.

It should be understood that the foregoing description includes many
10 implementation details that should not limit the scope of the present invention. For example, instead of using a proxy layer and a driver layer, the present invention may be implemented as a single abstraction layer between a telephony radio and a computer. The applications on the computer may communicate with the abstraction layer using top-level APIs. On the other
15 hand, the telephony radio would respond to commands received from the abstraction layer. Because the difficulties of implementing specific modules to understand different protocols such as TAPI, ExTAPI, SMS, etc. is accomplished by the RIL itself, the present invention eases the implementation difficulties radio manufacturers often have. Moreover, radio
20 manufacturers no longer have to worry about receiving and keeping track of calls from multiple client applications because all of these functions are handled by the RIL. Software application developers do not need to worry about the underlying hardware of a mobile device. Software applications may be easily written to work with RIL because the applications use well-

known top-level APIs which are sent to the RIL. The RIL will then perform appropriate processing of these top-level APIs and, if necessary, send the appropriate command to the radio to perform a specific action.

Other Supported Configurations

5 It should also be understood from the foregoing description, that the present invention may be used with cellular telephones as well as other devices, such as hand-held PDA devices. Some of these other devices may not have a permanent radio module(s). Certain changes known to those skilled in the art may be necessary to implement the invention in a device
10 without a permanent radio module(s). Specifically, the invention must support Removable Compact Flash (CF)/PCMCIA radio modules that support circuit-switched cellular network connections.

Listed below are some possible device configurations:

Configuration 1: Cellular telephone

15 The device has a built in radio-module. It does not have any expansion slots that support CF or PCMCIA cards. Therefore the built-in radio module is guaranteed to be always present and no alternative form of cellular communications is permitted.

Configuration 2: PDA with PCMCIA/CF support

20 The device does not have a built in radio-module. However, it does contain a CF and/or PCMCIA expansion slot(s). In a preferred embodiment, the invention requires that a supported Radio module be inserted into the CF or PCMCIA slot.

Configuration 3: PDA with built in Radio and PCMCIA/CF support

The device has a built in radio module. It can be assumed that this radio module will always be present. Potentially, one can insert other devices (including radio modules) into any available expansion slot
5 (PCMCIA, USB, Bluetooth, etc.).

The devices described above may also require a few additions and modifications to the API set as described below in an illustrative embodiment:

PDA Support API additions

10 Error Codes:

RIL_E_RADIONOTPRESENT

Fails the RIL calls because there isn't a radio present in the system

RIL_E_RADIOREMOVED

Fails the RIL calls which were in the process of being executed
15 because the radio was removed

PDA Notifications

RIL_NCLASS_RADIOSTATE

Radio State notifications (RIL_NCLASS_RADIOSTATE)

20

Notification Radio State Constants

RIL_NOTIFY_RADIOPRESENT

Notification corresponding to when the radio is inserted and the RIL Driver is ready to accept commands

5 **RIL_NOTIFY_RADIONOTPRESENT**

Notification corresponding to when the radio is removed and the RIL Driver is unloaded.

Additional Unrelated Notifications

10 **RIL_NOTIFY_RADIOOFF**

For SetEquipmentState TxandRX off command

RIL_NOTIFY_RADIOON

For SetEquipmentState TxandRX on command

15 Attached as Appendix A is a list of the RIL APIs of a preferred embodiment of the present invention. These APIs are provided as examples only and should not limit the present invention.